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AN ANALYSIS AND CONTROL OF DYNAMIC PROCESSES IN MECHANICAL PARTS OF POWER EQUIPMENT

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ABSTRACT

The article presents an approach to the analysis and control of coupled vibration processes of the part of power equipment in the context of the scientific field, the physics of open systems. Dynamic processes in the coupled nodes of complex mechanical equipment from the position of the interaction of multidimensional chaotic systems are investigated. A mathematical model is proposed for studying the processes of interaction, the effect of the field of the hindrances and the course of transient processes. The proposed algorithm for controlling the behaviour of the system allows you to model the interaction processes, evaluate information parameters and control the dynamics of the system to obtain satisfactory characteristics.

KEYWORDS: Vibration, Chaotic Processes, The Physics of Open Systems, Tsallis Entropy, Poincare Recurrence & Lyapunov Exponents

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Original Article

INTRODUCTION

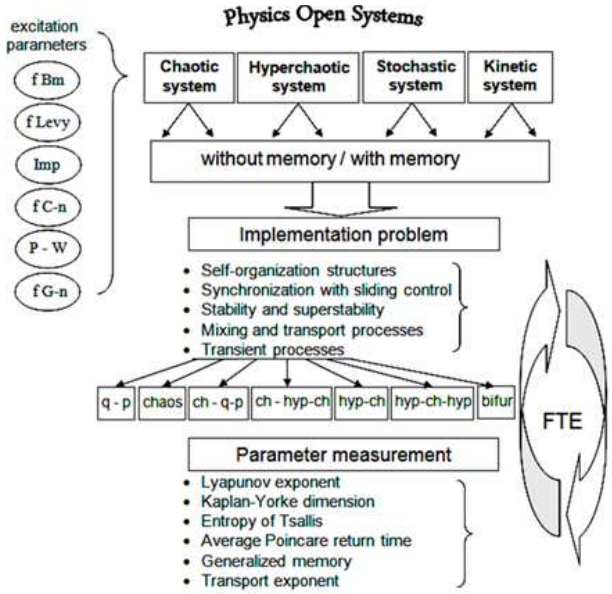
When monitoring the vibration activity of power equipment, for example, a hydroelectric power plant, a complex vibration signal is observed. The sources of such signals are: pulsations of the turbulent flow of the energy carrier-water, cavitation processes, and friction processes in the supports, and the nature of the load variation at the output of the hydro generator, the effect of parallel hydraulic units, various resonances, and much more. The joint manifestation of the activity of all these sources of vibration leads to the generation of complex signals demonstrating chaotic dynamics. It is known that the possibility of amplifying or suppressing the randomness of the regime in nonlinear dynamical systems is of great practical importance. These control methods are based on the phenomenon of the sensitivity of a system with chaotic dynamics to small perturbations [1, 2].

Registration and processing of the entire variety of the ongoing vibration processes allow us to identify the centre of negative vibration from the positions of the information object, dangerous trends in the development of controlled parameters. Informative visualization of ongoing dynamic processes is an important fragment of ongoing research. A great help in assessing the dynamics of controlled nodes can be the construction of recurrent diagrams, based on visual images of which one can interpret the situation created and make a decision on the effect on the monitored node for suppressing or modifying the effect of its negative vibratory activity [1, 2, 3]. Education and knowledge are important keys for human being. The correlation between education and the prosperity of society is well established. The importance of education has been universally acknowledged and accepted, but the phenomenon of exclusion of larger sections of the population and the drop outs from the formal education systems

is one constraint. Academic and professional up-gradation, the professional training that would enhance the performance in traditional occupations and the intellectual growth, is required in today's time.

ANALYSIS AND CONTROL OF NONLINEAR SYSTEMS

Now in science, more attention is paid to the role of chaos in the evaluation and management of the development processes of nonlinear systems, the features of the development of multidimensional processes in fractional chaotic systems. Moreover, the dynamics and evolution of open systems are described in terms of attractors, transient processes, stability, bifurcations, etc. As a result of such a change of structures, the system can fall into states, for example: chaos - quasi-periodicity, chaos-hyperhaos-chaos, hyperhaos-chaos-hyperchaos etc. [4]. The development of transient processes can depend on both internal and external disturbances. The foregoing is typical for the "Open System" with the structure of studies of multidimensional chaotic, stochastic and kinetic systems (Fig. 1) [5, 6, 7, 8].



Legend:**fBm** – fractional Brownian motion; **fLevy** – fractional Levy motion; **Imp** – impulsive function; **fCN** – fractional Colored noise; **P-W** – piecewise function; **fGn** – fractional Gaussian noise; **q – p** – quasi-periodic; **ch – q-p** – chaos – quasi-periodic; **ch-stoch** – chaos – stochastic; **ch – hyp-ch** – chaos – hyper-chaos; **hyp – ch – hyp** - hyper-chaos - chaos - hyper-chaos; **bifur** – bifurcation.**F T E** – fractional time evolution.

Figure 1: Research of Fractional Chaotic Systems.

The presented scheme of relationships and interrelations of problems, types of impacts and the main parameters of the monitored system shows the main provisions and structure of research. New opportunities in mathematics and theoretical physics of open systems allow us to consider systems whose order of differential operator are an arbitrary parameter. Here the fractional derivative index allows us to consider the singularities of open systems.

The accompanying impacts on the chaotic system of the transient process, the parameters of which change over time, are also of interest for determining the control strategy. The application of Poincare recurrence is an important aspect in the study of evolution and dynamics of transient processes [3].

The influence of various environmental factors causes a deviation of the state of the open system from the equilibrium position and leads to: the emergence of correlation interactions between the individual elements of the system; violation of the properties of ergodicity, additivity and local equilibrium; reduction of entropy production; fractions of the

internal structure; the search for a new stable state system and a search of possible structures [5, 8].

It should be noted that the transient process can be caused both from the manifestation of internal and external disturbances. Thus, models of strange kinetic phenomena in turbulent media are the Levi processes and random walks in fractal time [9, 10].

TOPOLOGICAL SYNCHRONIZATION AND TOPOLOGICAL CONTROL

An example of the practical implementation of solving topological synchronization problems and topological management, in contrast to the traditional approaches [11], can be a scheme of iterative learning with a fractional order [12].

The scheme of iterative learning with fractional order is given as [13, 14]:

$$U_{k+p}^{(\alpha)}(t) = F(U_k(t), e_k(t)),$$

where $e_k(t) = Y_d(t) - Y_k(t)$.

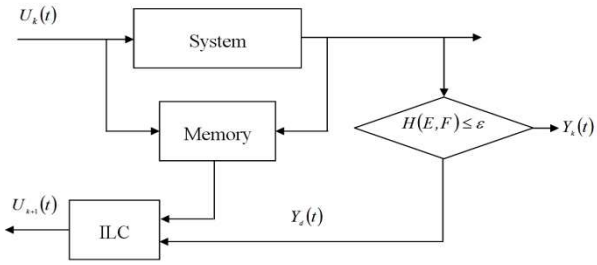


Figure 2: The Basic Scheme of Iterative Learning Control with $Y_d(t)$ being the Trajectory, $U_k(t)$ and $Y_k(t)$ the Input Signal

The procedure of iterative training and control includes steps on system simulation, topological synchronization, estimation of the Poincare return time spectrum, construction of a recurrence diagram, determination of system stability, and others [14].

ANALYSIS OF TRANSIENT PROCESSES IN COUPLED HETEROGENEOUS CHAOTIC SYSTEMS

The purpose of the analysis is to study the dynamics of transients in interacting components and in the hydro unit as a whole. The results of the research will allow developing a strategy for organizing coherent behaviour of the coupled nodes of the system, and through control and exposure, corrective actions will achieve obtaining characteristics that satisfy the user's requirements. When modelling the processes of self-organization in open systems that are in disequilibrium with the environment, it is necessary to take into account both the physical exchange processes between the open system and the environment, and the exchange of information flow [4], [5], [15].

Based on the analysis of the interaction parameters of fragments of a complex system, a mathematical model of the type was proposed:

$$s_q = \left[\left\{ \sum_{i=1}^{N} s_q(D^q x) + \frac{1-\hat{q}}{n} \prod_{i=1}^{N} s_q(D^q x) \right\} + GM \right]$$

where S_q in the entropy of the Tsallis, $D^q x$ - fractional dynamic systems, N - number of elements in the system, GM - generalized memory [7, 12, 16], n - parameter.

The proposed expression characterizes the thermodynamic category, which is exchanged with a complex system within the framework of the transition process [15]. It is proposed here to use the entropy of Tsallis as a measure of the coherence of coupled multidimensional chaotic systems. Taking into account that entropy oscillations (coherent oscillations) will arise during transient processes, as well as in the case of noise effects and resonance excitation, stability issues of coherent processes acquire the primary importance [15].

Based on the thermodynamic-information aspect of the mathematical model of transient processes in chaotic systems, the structure of the algorithm for organizing the coherent behaviour of systems is proposed in Figure 3 [15].

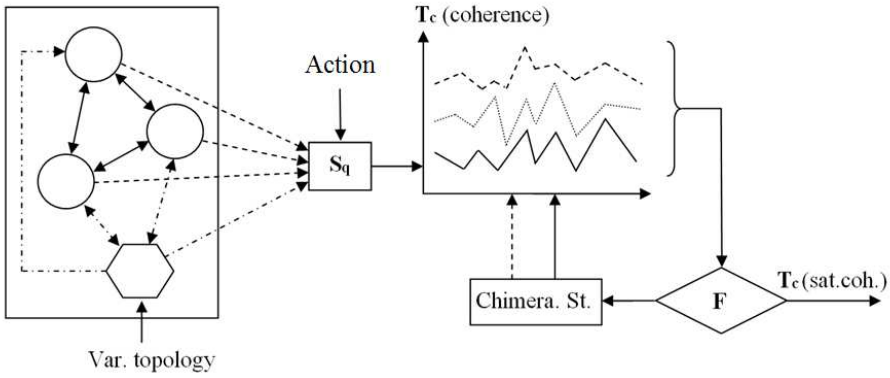


Figure 3: The Structure of the Algorithm for Organizing the Coherent behaviour of Systems

The work of the algorithm consists in performing the iterative method of resonant excitation with monitoring the parameters of the system characteristics that meet the requirements of satisfactory characteristics. Here, as a corrective influence, the spatial-temporal structure of the Chimera is chosen, in which the systems of identical oscillators are divided into coexisting regions of coherent and incoherent oscillations. The state of the chimera is a manifestation of a complex, chaotic transient process in the system [17, 18, 19].

CONCLUSIONS

- The stages and objectives of the study of the dynamics of complex, interrelated systems are formulated.
- The structure of studies of a complex dynamic object functioning within the framework of the Open System is proposed.
- The scheme of the iterative learning algorithm for solving topological synchronization problems is presented.
- A mathematical model is proposed, formulated in the aspect of thermodynamic information.
- An algorithm for implementing non-traditional control over the behaviour of a complex system is presented to achieve satisfactory characteristics.

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